IV. REMARKS

Claims 1-17 stand rejected, under 35 USC §103(a).

In the present Office Action, claims 1 and 2 stand rejected under 35 USC 103(a) as being unpatentable over U.S. Patent 6,767,530 ("Kobayashi"), in view of U.S. Patent 2,556,835 ("Barr") and any one of U.S. 6,696,506 ("Tonkovich et al.") and U.S. Patent 5,763,114 ("Khandkar et al.").

This rejection is respectfully traversed in part.

The Examiner correctly notes that Kobayashi teaches a process for producing hydrogen comprising steam reforming in a regenerative bed reactor followed by a shift reaction to increase hydrogen concentration, followed by conventional pressure swing adsorption.

A closer examination of Kobayashi reveals that the above three reactions are accomplished by

1. Feeding steam and feed to a heated regenerative reactor (6),
2. Passing the hot synthesis gas through a furnace (15),
3. Passing the hot synthesis gas through a gas cooler (8),
4. Passing the cooled synthesis gas through a optional shift reactor (27),
5. Passing the synthesis gas through a second gas cooler/regenerative heat recovery bed (21), and finally
6. Passing the synthesis gas to a PSA reactor (10).

This is Kobayashi's first half of the reforming/regeneration cycle. He teaches performing this portion of the cycle "until the adsorber becomes saturated with carbon monoxide, carbon dioxide, water and other gases." Before saturation, the hydrocarbon feed is turned off and "forward cycle" runs on steam to purge the reactor bed

combustion chamber and both heat recovery beds to prepare for the next cycle. All steps are performed serially.

Kobayashi then commences his regeneration or reverse cycle. Kobayashi's regeneration cycle comprises:

7. Desorbing gas species (mostly CO and CO_2) at reduced pressure ("tail gas"),

8. Passing this tail gas through the second heat recovery bed (optionally bypassed for tail gas, serving instead as a pre-heat apparatus for oxidant),

9. Passing the tail gas through the shift reactor (optionally bypassed for tail gas),

10. Passing the tail gas to a further heat recovery bed, previously heated to preheat the CO_2 of the tail gas (optionally bypassed for tail gas, serving instead as a pre-heat apparatus for oxidant),

11. The pre-heated CO_2 is further heated in a furnace,

12. Thereafter, an oxidant is added, and passed to a burner furnace for combustion, and

13. The heated combustion stream is then passed from the furnace zone to the regenerative reactor bed to reheat that bed for the next cycle's reforming (see Col. 5, line 2 through Col. 6, line 11).

These processes are all also done serially.

As previously noted, applicants' invention differs from Kobayashi's in at least two substantial ways:

- the actual reforming step and the first step of heat recovery are done at a space velocity of at least 1000 hr^{-1}, and
- the "reverse or regeneration cycle" of applicants' process uses only the regenerative zone and reforming zone.

In his Office Action, the Examiner contends that it would have been obvious to one of ordinary skill in the art at the time the invention was made to optimize the pressure of the process, and that the artisan would have been motivated to optimize the pressure by controlling flow rates of feed and product streams to elevate process pressure as is well known in the art.

The Examiner additionally contends that Barr teaches a process for producing hydrogen wherein the reforming process is carried out under pressure for the purpose of avoiding compressing costs and concludes that it would have been obvious to one of ordinary skill in the art to provide a reforming process is carried out under pressure in Kobayashi in order to avoid compressing costs as taught by Barr.

Applicants respectfully traverse this basis of the Examiner's rejection, noting that the operating pressure differences between their invention and the cited art, alone, are not the basis of patentability. These bases, when combined with the distinction of high space velocity and a "reverse cycle" of the regenerative reformer bed that does not involve the multiple reactors and apparatus of Kobayashi's reverse cycle, distinguish the applicants' invention from Kobayashi et al, alone or in view of Barr. Details of these distinctions follow below.

At page 5 of his Office Action, the Examiner acknowledges that Kobayashi does not teach the claimed space velocity of the present invention. The Examiner contends, however, that processes for hydrocarbon reforming reactions at high space velocities are well known as taught by either Tonkovitch or Khandkar. Applicants respectfully traverse this basis of the Examiner's rejection.

Applicants acknowledge that there are multiple examples within the relevant prior art of high space velocity steam reforming. However, none teach high space velocity reforming in cyclic, regenerative bed generators, as claimed in the present invention. Tonkovich and Khandkar both exemplify processes for high space velocity

reforming. Both are continuous, steady state systems, not regenerative bed systems. A skilled practitioner readily recognizes that the process conditions and reactor design of a continuous, steady state reformer would not teach, motivate, or even suggest the successful design of a cyclic regenerative bed system, as claimed herein. Tonkovich teaches high space velocity steam reforming to reduce the size of the reactor device. Tonkovich teaches separate (but proximate) reaction "channels" for the endothermic reforming reaction and a exothermic combustion reaction, not a cyclic regenerative bed. Khandkar teaches a high space velocity steam reforming reactor located within a furnace. A close reading of Khandkar identifies that although the manufacturer of his SOFC suggests a reforming space velocity of 2000 hr^{-1} is feasible for this continuous, steady state reformer, Khandkar discovered that his reforming reaction should be heating rate limited and teaches a space velocity of 350 hr^{-1} for his feed (equating to C_1GHSV of about 135). Neither Tonkovich, nor Khandkar, suggest the application of their high space velocity steam reforming to the cyclic, regenerative bed configuration of Kobayashi.

To sustain a rejection of obviousness, the Examiner need show two factors being met by the art relied upon. First, that the references would have suggested to those of ordinary skill in the art that they should carry out the claimed process, and that in carrying out the process, the skilled artisan would have reasonable expectation of success; In re Vaeck, 497 F.2d 488 @ 493 (Fed. Cir. 1991). Kobayashi neither teaches nor suggests how the skilled artisan would configure its apparatus or modify any of its process conditions to accomplish a space velocity of at least 1000 hr^{-1} in the reforming and heat recovery step (as claimed herein). Kobayashi's multiple, serially performed steps in the first (reforming) cycle would pose a virtually insurmountable hurdle to the skilled practitioner to design for these space velocities for both the reforming step and the heat recovery step(s). Tonkovich does not teach or suggest how a skilled practitioner would apply their high reforming gas velocities (i.e. greater than 10,000 to over 10^6 hr^{-1} to the regenerative bed system of Kobayashi. Since Tonkovich is a continuous, steady state system, he need not consider how such space velocities would

be achievable, and efficient, in the regenerative heat recovery step(s). Simply stated, there is virtually no expectation of success in applying the high space velocities of Tonkovich or Khandkar to the regenerative bed reforming system of Kobayashi, and no suggestion (nor expectation of success) of applying high space velocities to the heat recovery steps of Kobayashi. The same logic applies in respect of Khandkar. There would be no expectation of success in applying the high space velocities of Khandkar to Kobayashi.

Additionally, Kobayashi teaches the serial use of each zone or region in both the forward and reverse cycle (see Figures 1 and 2). This entails multiple reactors and multiple beds. In contrast, applicants' shift and separation means are performed only in the "forward" or syngas/hydrogen production cycle. In so doing, applicants substantially reduce reactor volumes that are subject to reverse-cycle flow. Kobayashi's lack of concern for reactor volumes evidenced by all reactions being serial and required for each cycle, teaches away from a consideration of high space velocity. Finally, Kobayashi teaches running the reforming cycle until the PSA adsorbent is saturated, which also may be considered teaching away from the high space velocity reforming taught herein. For at least these reasons, applicants submit that their claims 1 and 2 are not rendered obvious by Kobayashi in view of Barr and either Tonkovich or Khandkar.

Claims 3-8 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Kobayashi in view of Barr and Towler, and any one of Tonkovich or Khandkar. Applicants respectfully traverse this rejection.

For at least the above stated reasons, applicants submit that their amended claims are not rendered obvious by Kobayashi in view of Barr, and any one of Tonkovich or Khandkar. In adding Towler to this rejection, the Examiner contends this reference teaches a reformate effluent stream temperature below 700°C that is passed to a water gas shift reaction at about 400-450°C. More specifically, the Examiner contends it

would have been obvious to one of ordinary skill in the art at the time applicant's invention was made to provide reformate effluent stream at a temperature below 700°C that is passed to a water gas shift reaction zone operated at a temperature of about 400-450°C and flue gas is at a temperature of 400-800°C for the purpose of providing heat to a steam reforming and pre-reforming zone in Kobayashi because it is well-known in the art to operate these substantially similar processes (reforming, water gas shift, combustion) at the claimed temperatures as taught by Towler.

Additionally, the Examiner contents Kobayashi teaches that it is known to use pressure swing adsorption process to separate hydrogen from other gases.

The Examiner further asserts that Kobayashi also teaches that at least part of the flue gas is recycled to the reformer and teaches a process for producing steam using indirect heat exchange, concluding it would have been obvious to use at least part of the flue gas created in the combustion process to produce steam because the flue gas is used in heat-exchange processes in the process and because steam is created in the process using indirect heat exchange.

Applicants respectfully traverse this rejection.

As noted in prior responses, Towler adds nothing to Kobayashi, Barr, Tonkovich or Khandkar in respect of operating a cyclic, regenerative bed reforming reactor at space velocities exceeding about 1000^{-1}hr, or reduced reactor volumes during the "reverse" cycle of the present invention.

Additionally, the Examiner mischaracterizes Towler's reformate effluent stream temperatures relative to applicants' method for achieving a syngas temperature of about 220°C to about 400°C (claim 5). Applicants respectfully submit their amended claims, clarify where their effluent temperatures are measured, and how they are achieved. The 700°C effluent temperature recited in Towler is at the exit of the reforming bed

(col 13, lines 7-10). Towler controls this temperature by the amount of air added to its partial oxidation reaction (col 13, lines 54-58). That 700°C syngas is then cooled by combining with water (col 14, lines 1-3) to a temperature between about 400°C to about 450°C. In contrast, as stated in amended claim 5, applicants' regeneratively cooled syngas temperature is measured at the outlet of the regenerative zone, controlled by the zones heat transfer properties as taught by the specification.

At page 7 of his Office Action, the Examiner additionally asserts that Towler teaches combusting waste products with air to produce flue gas (col. 6) wherein the flue gas is at a temperature of 400-800°C for the purpose of providing heat to the steam reforming and pre-reforming zone (col. 12). The Examiner concludes that it would have been obvious to provide a flue gas at a temperature of 400-800°C for the purpose of providing heat to the steam reforming and pre-reforming zone in Kobayashi because it is well-known in the art to operate these substantially similar processes (reforming, water gas shift, combustion) at the claimed temperatures as taught by Towler.

Applicants respectfully assert that here again the Examiner mischaracterizes an analogy between Towler's process temperatures and the temperatures taught herein. The Towler 400°C to 800°C "flue gas" is used to provide heat to the steam reforming zone (col 12, lines 57-62). In their amended claims, applicants clarify where their "flue gas" temperatures are measured, and how they are achieved. Applicants regeneratively cooled "flue gas" recited at claim 6 is the regeneratively cooled effluent (137) after regenerating the reforming bed.

For at least the reasons stated above, Kobayashi, in view of Towler, does not teach the method for achieving the cooled syngas. Applicants additionally rely on the above noted distinctions, in respect of claims 1, 2 and 3, for the patentability of claims 4, 6, 7 and 8.

Claim 9 stands rejected under 35 U.S.C. §103(a) as unpatentable over Kobayashi, or alternatively in view of Barr in view of Hirata and any one of Tonkovich or Khandkar. This rejection is respectfully traversed for the same reasons stated above in respect of claims 1, 2, 3 and 5.

At page 8 of his Office Action, the Examiner has rejected claims 10-15 and 17 under 35 U.S.C. §103(a) as unpatentable over Kobayashi in view of Barr and Towler and Sederquist and anyone of Tonkovich or Khandkar. This rejection is respectfully traversed in part.

The Examiner concludes that it would have been obvious to one of ordinary skill in the art at the time the invention was made to optimize the pressure of the process, since it has been held that discovering an optimum value or a result effective variable involved only routine skill in the art, citing In re Boesch, 617 F.2nd 272, 205 USPQ 215 (CCPA 1980).

As explained above, applicants do not rely solely on the pressure ranges specified in its claims, for patentability, but all the process distinctions set forth in the claims that distinguish this invention from the cited art.

Applicants repeat here their remarks in respect of the teachings of Kobayashi in view of Barr and Towler and any one of Tonkovich or Khandkar, and now address the additional reference of Sederquist.

Applicants agree that Sederquist, in at least one embodiment, teach a reforming process for producing hydrogen having two zones, a first containing packing comprising alumina or magnesium oxide and a steam reforming catalyst and that packing material may be present in both zones. These teachings add no basis to Kobayashi, Barr, Towler, Tonkovich or Khandkar, to render the applicants' amended claims 10-15 and 17 obvious. Notwithstanding the Examiner's combining of five references, none of these references teach or suggest, alone or in any combination, a

cyclic regenerative bed reformer having the space velocity of the presently claimed invention, nor the reverse or regenerative cycle limited to the regenerative bed reforming and regeneration reactors. No combination of five references teach or suggest these distinctions.

The space velocity of the claimed process is not a routine process variable as the skilled artisan might view temperature, pressure, etc. Space velocity, in this application, articulates the process conditions reflecting a complex interdependence of many factors including reactor configurations, reactor internals (i.e. beds and catalyst) and heat transfer characteristics, all of which have complex inter dependence. Applicants have discovered that they can efficiently produce hydrogen under these complex conditions that no one has previously accomplished.

Applicants believe they have addressed each of the Examiner's rejections, setting forth the basis of distinction(s) of their invention over the prior art. If there are any remaining issues, the applicants urge the Examiner to call their undersigned attorney.

Respectfully submitted,

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[X] Pursuant to 37 CFR 1.34

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